ENVIRONMENTAL TOBACCO SMOKE

Measuring Exposures and Assessing Health Effects

Committee on Passive Smoking
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Assessing Exposures to Environmental Tobacco Smoke Using Questionnaires

The active component(s) of environmental tobacco smoke (ETS) associated with various health effects may be different for acute and chronic outcomes. Also, the mechanisms of action differ. Furthermore, as discussed in Chapter 2, the relative concentrations of various components of ETS change over time, i.e., as the smoke ages. Therefore, the use of a single proxy pollutant, such as respirable particulates, or an indirect measure of ETS limits the ability to assess responses to ETS exposure. For some investigations, indirect assessment is probably not adequate to evaluate health effects for at least two reasons. First, the tobacco smoke components that affect the health outcome may not be related to the indirect assessment in a simple way, e.g., vapor-phase-component concentrations cannot be adequately measured by particulate-phase components. Secondly, a variety of host factors affect the actual dose received so that assessment of exposure does not accurately (or completely) represent dose (see Chapter 7).

A variety of methods is used to estimate individual exposures associated with human health effects in industrial and nonindustrial settings. These exposure indicators may be direct—such as the use of personal-monitoring data or biochemical measures obtained by testing body fluids for the compound or its metabolites—or indirect—such as the use of data from interview responses of family members regarding activities of the subject and modeling based on environmental monitoring of the ambient or industrial setting. The resulting data from direct and indirect indicators of exposure can be expressed in quantitative or qualitative terms.

The advantages and disadvantages of the various exposure measures used in industrial and nonindustrial settings are summarized in Table 6-1. The issues raised in this table are directly relevant to assessing ETS exposure. The use of surrogate measures derived from questionnaire responses and the issues resulting from use of these measures are discussed in this chapter.

EXPOSURE HISTORIES DERIVED FROM QUESTIONNAIRES

Questionnaire responses of study subjects or family/household members are used for two purposes. First, questionnaires are used to obtain data on the physical characteristics of each environment and the time-activity patterns of the individual in each environment. These data can be used with individual monitoring data to estimate (usually by modeling) the air-contaminant levels in the microenvironment and to estimate time-weighted, integrated individual exposures. Second, questionnaire responses provide a basis for classification of individuals into broad categories of exposure based on self (or proxy) reports of exposure to individuals who smoke. Questionnaires of the latter type have provided the bases for associating ETS to the increased risk of nonmalignant and malignant disease.

There are several major issues in epidemiologic studies of health effects of exposure to ETS that rely on indirect measures of exposure as derived from questionnaire data.

First, the assessment of ETS exposures associated with acute health effects requires a different approach than that for chronic health effects. Acute health effects, such as respiratory infections, are manifested shortly after exposure and are of short duration. By inference, these health outcomes depend only on exposures in the recent past. In contrast, chronic health effects are conditions that are associated with long-term exposure to ETS, that is, they are manifested after some prolonged period of time and are of long duration. In evaluating the association of ETS with chronic diseases, knowledge about the duration of exposure and the duration of time from initial exposure to disease onset is more important than the duration of the disease.

Second, quality of information obtained by interview or self-administered questionnaires may vary among studies and may vary for different disease outcomes. For example, the assessment

TABLE 6-1 Indicators of Individual Exposure in Industrial and Nonindustrial Settings—Advantages and Disadvantages

Indicator	Advantages	Disadvantages
1. DIRECT		
A. Biologic monitoring of body fluids for the compound and/or its metabolites—*quantitative* (e.g., blood level)	1. Identifies exposed individuals 2. Provides measure of body burden for some agents (e.g., metals) 3. Measures absorption of compound from all routes of entry—respiratory, cutaneous, and oral 4. Gives information about prior exposure	1. Many methods still in developmental stages and lack validation 2. May be expensive due to need for specially trained personnel and sophisticated equipment 3. May require concurrent air sampling if exposures are not constant 4. Interpretation may be influenced by variation in uptake with physical exertion and interference from diet and drugs 5. Requires careful timing of specimen collection, especially for blood samples 6. Subject consent required to obtain specimens 7. Lack of population reference values
B. Personal industrial hygiene or ambient monitoring, single and multiple—*quantitative*	1. Estimates exposure for individual employees 2. Can be performed easily by the employer 3. Exposure to multiple compounds can be assessed simultaneously	1. Requires cooperation of worker or study subjects to wear monitoring equipment 2. Does not measure body burden 3. Limited ability to assess multiple routes of exposure 4. Gives no information about prior exposures 5. May not correspond with results of area sampling 6. Samples may not reflect "average" work day; taking of measurements should consider shifts, production, seasons, etc.

TABLE 6-1 *Continued*

Indicator	Advantages	Disadvantages
C. Employer or other reports of exposure to compound—*qualitative*	1. Provides details of accidental releases 2. Can indicate safety procedures/protective measures	1. Data may be incomplete (unreported) 2. Exposure quantified subjectively 3. Episodic measurement of unusual occurrences rather than "average" workday exposure
D. Self-reports of exposure to compound—*qualitative*	1. Provides details of accidental releases 2. Can indicate personal hygiene and safety habits 3. Can obtain chronology of work experience with multiple agent exposures	1. Potential for recall bias 2. Employees may be unaware of exposure 3. Potential for falsification of exposure for personal gain 4. Potential for lost to follow-up (missing information) in retrospective studies
2. INDIRECT		
A. Biological monitoring		
(1) with chromosome studies—*quantitative* or *qualitative*	1. Identified changes in the genetic material 2. Indicates systemic exposure to a mutagen	1. Expensive, due to need for specially trained personnel and sophisticated equipment 2. Relationship between changes in mutation rates and reproductive outcomes is unknown 3. Results may be confounded by smoking and environmental factors (e.g., effect of smoking on sister chromatid exchanges in lymphocytes; radiation effects) 4. Individual variability in baseline rates 5. Most chromosomal aberrations are nonspecific
(2) by measuring changes in biochemical responses (e.g., elevated rate of thiocyanate production in	1. Identifies alterations in normal constituents of body fluids and changes in rate of normal biochemical processes	1. Does not quantify body burden 2. Results may be confounded by drugs, nutrition, and disease

response to cyanide exposure)—*quantitative* or *qualitative*		3. Requires understanding of compound's metabolism in body
B. Area industrial hygiene or ambient monitoring—*quantitative*	1. Documents concentration of agent in work environment 2. Variety of measurement techniques available 3. Can be performed easily by the employer	1. May not correspond with results of personal sampling 2. Measurements have multiple sources of variation 3. Does not indicate specific exposure level for individual employees 4. No information about previous exposures 5. Type of sample taken may be inappropriate for health effects being studied
C. Employer work area assignment records (work histories)—*qualitative* (specific estimates may be made using job-exposure linkage) or *quantitative* (may be developed by using duration of time spent in different environments) Activity diaries of study subjects, recording time spent in different microenvironments	1. Can provide chronologic work experience for duration of exposure 2. Can indicate exposure to multiple agents 3. May provide supplementary information	1. May be incomplete or may be unavailable 2. Records not designed for research purposes 3. Presumed exposure by work assignment may be based on subjective criteria 4. Record review is time-consuming
D. Surrogate (next of kin) interview responses regarding work history and activity history of study subject—*qualitative* (specific estimates made using a job-exposure linkage) or *quantitative* (estimates developed using duration of time spent in environments)	1. Can obtain information about confounding factors 2. Identifies major agents to which exposed 3. May provide supplementary demographic information about employees	1. Limited by knowledge of employee's work 2. May produce overestimate or underestimate of exposure 3. Time-consuming to locate and interview 4. Lack of validation of data 5. Differential quality of information by degree of kinship

of maternal smoking during the first year of life of a child may be a much more accurate measure of exposure to ETS related to respiratory illness than a summary history of ETS exposure related to lung cancer. Data quality for ETS exposures can be affected in major ways by differential and nondifferential misclassification of exposure. In Chapter 12, the impact of misclassifying exposed subjects as nonsmokers, when they are in fact current smokers or exsmokers, is discussed. Therefore, it is important to determine whether nonsmoking subjects are, in fact, never smokers or currently nonsmokers, i.e., exsmokers. Another source of bias is the misclassification of exposure among nonsmokers. That is, nonsmokers who say they have not been exposed may in fact have had significant exposures. In both cases, detailed probes are needed.

Third, the role of major confounding exposures needs to be assessed. For instance, occupational exposures to other air contaminants may cause pulmonary disorders.

Fourth, the evaluation of ETS exposures should attempt to assess all such exposures rather than focus solely on exposures from smoking by family members (spouse, mother, or father) or focus solely on the home environment. An adequate assessment of total ETS exposure will necessitate a consideration of exposure levels in specific microenvironments—such as home, school, work, vehicle, and recreation—and the duration of time an individual is exposed in these environments. Developing such a measure is complex even for relatively acute health outcomes, such as acute cardiovascular, respiratory, or neurotoxic symptoms, for which it may be sufficient to estimate recent exposures. Developing a comprehensive measure to ETS exposures is far more complex for diseases with long induction times, such as cancer and chronic obstructive pulmonary disease. The data required for modeling a long-term integrated ETS exposure may be far more detailed than are available or can be reliably obtained. Further, when a surrogate informant is used, that person most likely will be able to report on exposures in only some of the microenvironments. In this case, it may be impossible to develop a comprehensive index.

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ENVIRONMENTAL TOBACCO SMOKE EXPOSURE DATA FOR STUDIES OF ACUTE AND CHRONIC HEALTH EFFECTS

The acute health effects of ETS in children, such as respiratory illnesses, have been assessed in the National Health Interview Survey (NHIS) by determining smoking status of one or both parents or smoking status of adults in the household (Bonham and Wilson, 1981). In this national probability sample of households, parental smoking histories and reports of respiratory illness among children were obtained at one point in time. By contrast, in the Harvard Air Pollution Respiratory Health Study (Six Cities Study), information on current smoking habits for parents and all household members who smoke regularly in the home is obtained annually to determine amount of cigarette smoking in the home environment to which the children aged 6-13 years are exposed (Ware et al., 1984). (In Chapter 11 the assessment of exposure to parental smoking in studies of respiratory illness in children is discussed in more detail.)

In studies of chronic health effects in adults, such as cancer, exposure of nonsmokers to ETS has been largely determined by smoking status of the spouse. Most studies of lung cancer among nonsmoking women have relied solely or principally on information regarding smoking status of the spouse to assess ETS exposures, with little attempt to corroborate self-reports of exposure to ETS.

The difficulties in assessing ETS exposure are similar to difficulties of assessing occupational exposures (Axelson, 1985). Both exposures are complex and variable. The problem of obtaining adequate information about ETS exposure might be overcome by obtaining data from multiple respondents and by using corroborating procedures. However, the conceptual difficulty concerning the determination of exposure is unresolved or unaddressed in most studies. Exposure to a substance involves a varying intensity over some period of time prior to the development of disease. These factors may influence the absorption and distribution of an agent in the body as well as the biotransformation and excretion of the agent. Therefore, these factors probably influence the risk of the health outcome of interest. For exposures extending over long periods of time, a simple "cumulative dose" usually is calculated by a time integration of the intensity. The estimate of

exposure over long periods of time is expressed as average number of cigarettes per day or the calculation of "pack years." This type of measure does not provide for an independent consideration of latency, does not consider variability in exposure over the time period, and represents two components of exposure, one of which may be more precisely measured (duration) than the other (intensity) (Doll and Peto, 1978). Axelson (1985) describes some sophisticated adjustments that have been proposed for weighting time periods of exposure to estimate cumulative-dose measures.

These proposed methods have not been widely adopted, probably due to both the complexity of the method as well as the recognized limitations of exposure data typically available. The more common, simplified procedure is to apply an appropriate induction/latency period in the analysis of studies of cancer or other chronic diseases. This practice suggests, however, that more attention be given to identifying the separate effects of late (recent) exposures versus early (remote) exposures on development of various diseases. These effects may also be mediated by the age at which the exposures occurred.

The proposal described by Johnson and Letzel (1984) advocates a method of assessing exposures to ETS experienced over an entire lifetime. The major limitation of this approach is that it has not been validated. Johnson and Letzel (1984) argue that since no objective criteria for lifetime exposure to ETS exists, a direct validation of an instrument to assess lifelong ETS exposure cannot be obtained. They propose that the instrument be validated on a recent time frame, such as 24-hour data. From these data the investigators argue by analogy that the method, when expanded to a longer time frame, can be regarded as valid. While this approach may seem less than ideal, the constraints due to data availability and quality emphasize the importance of the type of methods development and corroboration illustrated by the work of Johnson and Letzel (1984).

DATA QUALITY

Misclassification of individual ETS exposure may be differential (biased) or nondifferential (random). Differential misclassification would result in a distortion of the estimate of risk in either direction, depending on the direction of the misclassification. Nondifferential misclassification would result in a reduction

of power in a study, thus making it more difficult to detect a true association of exposure with risk of disease.

One form of differential misclassification that is a major concern in studies of ETS exposures is the active smoking status of study subjects. This misclassification may be considered differential because spouses and children of smokers are more likely to be smokers (or have smoked) themselves, even though they are reported as "nonsmokers." The effects of this differential misclassification are discussed in Chapters 11 and 12. One way to minimize this problem is to have multiple questions that probe for previous cigarette usage, even if the subject has defined himself or herself as a nonsmoker.

Another form of differential misclassification is that resulting from the biased reporting of exposure to ETS by individuals with existing respiratory diseases, such as asthma or chronic bronchitis. One might conjecture that individuals with existing respiratory diseases may be more or may be less likely to report exposure to ETS than individuals without such existing conditions.

In studies of ETS exposures, information about the smoking habits of the subject, family, and household members is obtained by interviews with the study subject when available, or by interview with a family member when the study subject is deceased or unavailable. That is, surrogate respondents may be used to collect information regarding personal exposures of the study subject.

The validity of surrogate information in most studies is uncertain, and the direction of any potential bias is rarely known (Gordis, 1982). The feasibility of this approach for a variety of exposures and habits has been examined (Pickle et al., 1983). Also, several studies have assessed the reliability and validity of surrogate respondents for various kinds of exposures (Rogot and Reid, 1975; Kolonel et al., 1977; Marshall et al., 1980; Baumgarten et al., 1983; Humble et al., 1984; Greenberg et al., 1985; Herrmann, 1985; Lerchen and Samet, 1986). In all of these studies, agreement between self and surrogate responses improves when the amount of detail required for the response is decreased. This observation was first reported by Rogot and Reid (1975) and subsequently observed in studies comparing self versus spouse/surrogate responses.

Lerchen and Samet (1986) reported perfect agreement of cigarette-smoking status (ever/never) as reported by lung cancer cases and their wives, but only 66 (86%) of the 77 wives married to smokers were able to supply complete details about

their husbands' cigarette-smoking habits. In this study, agreement (expressed as correlation coefficients) was quite good for all smoking-related variables, such as age at which the subject started to smoke (0.48), total years of smoking (0.91), and average number of cigarettes smoked per day (0.44). The mean values reported by cases and their wives were not significantly different for any variable. Overall, the agreement observed for self- and surrogate-reported smoking-related information was better than the agreement for education, occupation, and dietary information.

Pershagen and Axelson (1982) also reported perfect agreement for smoking status information obtained by interview with a close relative (parent, wife, or child) for 14 lung cancer cases when information was compared with that obtained previously by the plant physician. Their inquiry was limited to smoker/nonsmoker status. Damber (1986) and Pershagen (1984) reported 99% agreement between reports of close relatives and hospital records for ever/never smoking studies in a sample of 86 patients admitted for respiratory disease. The agreement for number of years smoked (±5 years) was 74%.

Other studies have noted additional features of the responses from surrogates. The report by Pickle et al. (1983) indicates that respondents other than spouse and direct next-of-kin (siblings, parents, and children) are more likely to not know relevant information. Marshall et al. (1980) demonstrated the increase in sensitivity obtained by combining information from two or more surrogate respondents, and Herrmann (1985) showed that husbands reported data for wives as reliably as wives reported exposures of husbands.

Recent data from the NCHS Epidemiologic Followup Study (NHEFS) in 1982-1984 of participants in the National Health and Nutrition Examination Survey (NHANES I) in 1971-1975 provides a strong confirmation of these earlier reports (S.R. Machlin, J.C. Kleinman, J.H. Madans, National Center for Health Statistics, personal communication). This analysis is based on a subsample of 5,669 individuals with data regarding baseline smoking status available from both NHANES I and NHEFS. Agreement rates between NHANES I and NHEFS for the 5,029 subject responses versus the 640 proxy responses at follow-up are compared (Tables 6-2 and 6-3). When smoking status is broadly defined as ever/never, the 91% agreement rate for proxy responses compares quite favorably with the 95% agreement rate of subject responses

(Table 6-2). Similar high agreement is observed for proxy and subject responses at follow-up when smoking status is considered as current/not current (Table 6-3). Additional analyses of these data to assess the factors associated with agreement between baseline and follow-up responses considered age, race, gender of subject, type of respondent at follow-up, and smoking status at baseline. Estimates of the relative odds of disagreement indicated that only the effect of race did not interact with any of the other variables included in the multiple logistic model. Significant two-way interactions were observed for type of informant and age of subject, baseline smoking status and gender of subject, and baseline smoking status and age of subject. These results suggested that proxy respondents were more than twice as likely to misclassify smoking status for subjects less than 65 years of age, but not for subjects age 65 years and over. When amount smoked (current amount at baseline versus usual amount at follow-up) is compared for smokers only, the agreement rates are substantially affected by type of respondent; 55% agreement for subject responses versus 35% agreement for proxy responses. When this comparison is made with nonsmokers included, a much higher rate of agreement for both subject (80%) and proxy (74%) responses is observed. This comparison is strongly influenced by the substantial proportion of nonsmokers (over 60%). Of concern, however, is the high proportion of self-reported current and former smokers at baseline who are reported as never smokers at follow-up; 5.6% by self respondents and 12.9% by proxy respondents. These results are discussed later in the section concerned with confounding.

Another large cohort study in England and Wales provides information regarding the proportion of people who say that they have never smoked but, in fact, have done so in the past (N. Britten, University of Bristol, England, personal communication). A large longitudinal study of children born in 1 week in England and Wales in 1946 has included several follow-up visits, the most recent of which was done in 1982 when the subjects were 36 years of age. Table 6-4 presents some results. A portion (4.9%) of the subjects said they had never smoked as much as one cigarette a day in 1982 when in fact they had previously reported that they smoked. These subjects had reported smoking at a rate of about half the current smokers. Nearly all of exsmokers (93%) had smoked 10 or more years earlier.

TABLE 6-2 Percent Distribution of Smoking Status at Baseline Exam (NHANES I, 1971–75), According to Smoking Status at Follow-up (NHEFS, 1982–84) by Type of Respondent at Follow-up

Baseline Smoking Status (NHANES I)	Smoking Status Reported at Follow-up: Ever No.	Percent	Never No.	Percent	Total No.
	Type of Follow-up Respondent: Self				
Ever	2,675	95.6	125	5.6	2,800
Never	122	4.6	2,107	94.4	2,229
Total	2,797	100.0	2,232	100.0	5,029
	Type of Follow-up Respondent: Proxy				
Ever	329	95.1	38	12.9	367
Never	17	4.9	256	87.1	273
Total	346	100.0	294	100.0	640

SOURCE: Information obtained from National Center for Health Statistics (S. R. Machlin, J. C. Kleinman, J. H. Madans, personal communications).

TABLE 6-3 Percent Distribution of Smoking Status at Baseline Exam (NHANES I, 1971–75), According to Smoking Status at Follow-up (NHEFS, 1982–84) by Type of Respondent at Follow-up

Baseline Smoking Status (NHANES I)	Smoking Status Reported at Follow-up: Current No.	Percent	Not Current No.	Percent	Total No.
	Type of Follow-up Respondent: Self				
Current	1,722	89.5	124	4.0	1,846
Not Current	202	10.5	2,981	96.0	3,183
Total	1,924	100.0	3,105	100.0	5,029
	Type of Follow-up Respondent: Proxy				
Current	186	83.4	24	5.8	210
Not Current	37	16.6	393	94.2	430
Total	223	100.0	417	100.0	640

SOURCE: Information obtained from National Center for Health Statistics (S. R. Machlin, J. C. Kleinman, and J. H. Madans, personal communication).

TABLE 6-4 Smoking Habits of Cohort Members at Age 36 Who Previously Reported That They Had Smoked at Least One Cigarette a Day

Smoking Status Reported in 1982	Most Recent Age at Which Smoking Was Reported	Number of Subjects	Percentage of All Reported Ever-Smokers (No. = 2,080)	Mean No., cig./day	Interval Between Age Started Smoking and Age 36
Nonsmokers who had previously reported smoking (No. = 102)	31 yr (1977)	7	0.34	12.7	—
	25 yr (1971)	18	0.87	5.1	9.5
	20 yr (1966)	49	2.36	4.2	5.4
	<20 yr (before 1966)	28	1.35	5.8	1.8
	Total	102	4.90		
			Percent of Current Smokers (No. = 1,127)		
Current smokers who had previously reported smoking (No. = 1,048)	31 yr (1977)	819	72.67	20.6	
	25 yr (1971)	136	12.07	12.7	
	20 yr (1966)	84	7.45	11.4	
	<20 yr (before 1966)	9	0.80	16.1	

SOURCE: Based on data from the MRC National Survey of Health and Development (N. Britten, personal communication, University of Bristol, England).

Therefore, both longitudinal studies indicate that about 5% of self-reported lifelong nonsmokers may, in fact, have smoked. Rogot and Reid (1975) observed that there was a tendency of surrogate informants to report a higher tobacco consumption than previously reported by the study subjects. However, Lerchen and Samet (1986) observed no such differential in the reporting by wives of amount smoked by their husbands as compared with that reported by husbands.

The body of evidence on surrogate responses to questions about smoking status suggests that the validity of such data may be limited and that spouses and, perhaps, other close family members can provide an accurate, but simple, smoking history (ever/never, smoker/nonsmoker). However, detailed information about amount and number of years smoked may be inaccurate and may result in substantial misclassification of study subjects by exposure status. These findings, although from a limited number of studies, have direct implications for the studies of ETS exposures where ETS exposure information is derived from surrogate reports. It should be noted that in the special instance where the spouse surrogate is reporting on his personal smoking history, the information regarding ETS exposure of the nonsmoking study subject may be more accurate with regard to home exposures than the report by the study subject.

Cotinine, the major metabolite of nicotine, can be detected in blood, urine, and saliva of active cigarette smokers and of those passively exposed to ETS. Coultas et al. (1986) demonstrated that nonsmokers exposed to cigarette smoke in their homes have detectable levels of salivary cotinine that increase as the number of smokers in the home increases from 1 to 2 or more (Table 6-5). Biochemical corroboration is not as promising for remote exposures to ETS. Corroboration of historical exposures, therefore, must rely on other methods, such as review of historical records. Results of recent biochemical measures may be used to corroborate self-reports of recent exposures for individuals for whom reports of both recent and remote exposures are available. The quality of historical data for an individual can be inferred from data using results from biochemical corroboration. This approach has been proposed by Johnson and Letzel (1984).

The true validity of retrospective ETS exposures is impossible to establish. Wherever possible, other methods to corroborate exposure estimates should be used to assess and confirm the quality

TABLE 6-5 Salivary Cotinine Concentration (ng/ml) in Nonsmokers by Age and Number of Active Smokers in Household

	Number of Household Smokers		
Age, yr	None	One	Two or More
Younger than 6	0;1.7;68[a]	3.8;4.1;41	5.4;5.6;21
6–17	0;1.3;200	1.8;2.4;96	5.3;5.6;25
Older than 17	0;1.5;316	0.65;2.8;60	0;3.7;12

[a]Median; mean; number of subjects.

SOURCE: Coultas et al. (1986).

of self- and proxy reports of ETS exposure as well as active smoking status of study subjects. Other methods currently available for comparison with questionnaire and interview responses include biochemical measures, environmental modeling, review of existing records, and reports of additional respondents.

OTHER VARIABLES

Confounding factors that should be considered in the design, collection, and use of questionnaire data are other risk factors associated with the disease that may or may not be correlated with exposures to ETS. In the case of lung cancer, such risk factors include, but are not limited to:

- occupation and industry of employment,
- exposure to specific respiratory carcinogens, such as asbestos, arsenic, radon, etc., in occupational or nonoccupational settings,
- dietary factors,
- family history of cancer (Ooi et al., 1986),
- residential history,
- housing characteristics,
- years of education, and
- socioeconomic status.

Confounding factors relevant to the assessment of pulmonary function and respiratory illness are listed in Table 11-1. In addition, exsmokers and current smokers have been (or are) exposed to active smoking for some period of time. Therefore, these individuals may have been exposed to higher concentrations and longer

duration of ETS, due to their own smoking patterns. Thus, an evaluation of the increased risk associated with exposure to ETS for any disease that is strongly associated with active smoking will need to control for smoking status of the individual study subjects. The confounding effects of active smoking were not adequately controlled in several investigations of lung cancer (discussed in Chapter 12). This concern is particularly relevant in studies of acute respiratory illness in children and adolescents where the study subjects may be disinclined to report their smoking behavior accurately or the parents may be unaware of their child's active smoking (described in Chapter 11).

A history of exposure to all other known or suspected confounding factors should be obtained in a comparable manner for cases and comparison subjects by interview and corroborated whenever possible by comparison with existing records or self-reports obtained before development of the disease. The exposure data collected should strive to be as detailed as possible with respect to intensity, duration, and calendar time for all exposures, including ETS exposures. However, one should be cognizant of the limitations imposed on data quality, especially when the investigation relies on surrogate responses. Such quantification at best provides an approximation of exposure, whether the information is obtained from the individual himself or from a surrogate.

SUMMARY AND RECOMMENDATIONS

There are problems with self- and proxy reports of ETS exposure inferred from questionnaire responses that limit the utility of these data. The best method by which to estimate individual ETS exposures is not known, and this lack of information hampers all efforts at assessing data quality, including data validity. At present all methods used and proposed are indirect, although some provide quantitative measures and some qualitative measures (smoker/nonsmoker). However, information on exposure from monitoring and detailed environmental-modeling studies of RSP indicate that only 30-40% of the variation in exposure can be explained using this approach (see Chapter 5). Further, biochemical methods to assess ETS exposure are extremely limited in the assessment of historical exposures that are most important with regards to chronic health effects. Therefore, exposure data derived

from questionnaire responses have an extremely important role in existing and future studies of ETS exposures.

What Is Known

1. Surrogate responses from spouses or close family members can provide data as accurate as self-reports for simple ever/never smoker status and current amount smoked. However, with such simple classifications, an error rate of about 5% is observed whereby ever smokers are misclassified as lifelong nonsmokers. This error is present for self-respondents as well as proxies.

What Scientific Information Is Missing

1. Differences in exposure levels between home and work environments have not been described in existing studies. In addition to the amount of time that an individual may spend in a work setting, the actual exposure may vary within the setting due to physical characteristics of the work environment as well as the number of active smokers present.

2. Future investigations should be concerned with detailed characterization of ETS that would provide a more precise estimation of individual exposures and include additional considerations of physical characteristics of the environment, activity patterns of the study subject, and ages at which exposures occurred. These data could be entered into a model, from which exposure estimates can be made.

3. Because of the importance of misclassification of active smoking status, repeated and complementary efforts to determine and corroborate smoking status should be made in the collection of exposure data. Specific probes regarding former smoking status might be included in the questionnaire, even if the study subject has defined himself or herself as a nonsmoker.

4. Confounding factors should be considered in the design, collection, and use of questionnaire data. These will vary with the health effect being assessed. The evaluation of ETS exposures should attempt to assess all such exposures, including both the home and work environment rather than focus solely on the smoking status of one family member, e.g., spouse.

5. The comparability of questionnaires used to assess ETS has not been established, and this would be desirable.

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